LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Lubrication of Motor Coaches

FIFTEEN years ago buses were looked upon very much as an experiment. Ten years ago almost everyone regarded them as a novelty. Today, however, they are considered an absolute necessity and make up an important part of our modern transportation systems. Many persons will be justified in asking why has this new type of public carrier forged its way into the front ranks of popularity within such a relatively short period of time? Do these modern buses of ours possess the solution to present day transportation problems? Is this rapid expansion the result of greater comfort, more attractive appearance, or lower costs?

A few pertinent figures taken from transportation annals for the year 1937 furnish us with a very logical answer to the phenomenal expansion of the bus industry. For the year 1937 motor coaches carried six times as many passengers as were carried in steam railroads. While the investment of the bus industry is only 5 per cent. of the combined investment of all public carriers, including steam railroads, nevertheless they carried over 28 per cent. of the total passengers and collected over 27 per cent. of the total passenger revenues.* From a purely dollars and cents point of view, is it any wonder that this new form of transportation grew at such a rate which has never been witnessed before in our transportation industry. From the above figures, one can readily appreciate why the bus industry occupies the distinctive position today of being the only public carrier able to show a fair return on its investment. As a result of the low cost of operation of buses there are over 500 cities in the United States already served exclusively by buses and hundreds of other cities are known to be making plans for a complete change-over in the near future. Even the more conservative must agree that the saturation point of this unusual expansion is certainly not in sight.

To what extent does the Petroleum Industry fit into this bus transportation picture? The latest estimates reveal that Petroleum products rate second in importance of all materials purchased (exclusive of labor), including the purchase of new motor coaches. Twenty-seven cents of every dollar spent by the bus fleet for equipment and supplies goes for the purchase of petroleum products.

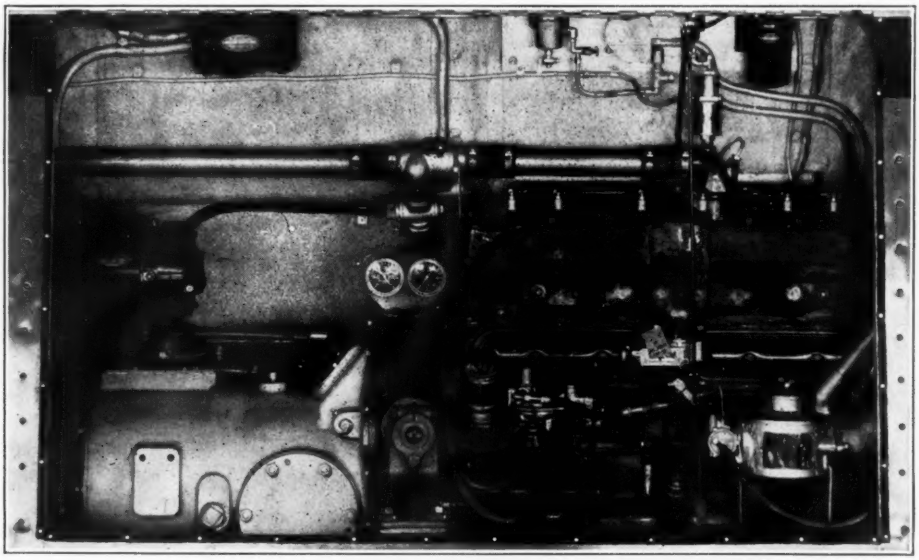
Thus it is easy to appreciate how closely the bus industry and petroleum industry are related. Each development brought forth by the oil refiner can readily mean a substantial saving to the bus operator. One of the most outstanding examples is found in the development of motor fuels with high anti-knock properties and commercially available at the present low prices.

This single property in gasoline has enabled engine designers to increase compression ratios to such an extent that over 50 per cent. more power is secured from an engine today than could be developed 10 years ago with an engine of equal piston displacement.

An increase in compression ratio often decreases the gasoline consumption to the point where the operator of a large fleet of buses may realize a saving of thousands of dollars annually. Similarly, past developments in motor oils

* Bus Transportation, January, 1938.

have reduced their consumption, increased their stability and enabled engines to function for long periods between overhaul. Gear oils and greases have likewise been improved to the point where they definitely save the bus operators hundreds and thousands of dollars in wear of transmissions, rear axles and chassis parts annually. The cumulative benefits of these developments mean greater profits, reduced fares and improved service.



Courtesy of Twin Coach Company
Fig. 1—Typical rear engine installation. Note gasoline engine at right and mechanical transmission at left.

The Petroleum industry has quickly realized that their responsibility does not end with the development of new fuels and lubricants, nor does it end with the sale of such products. What assurance does the bus operator have that he is receiving the best lubrication? Is it a matter of selling by a price list and sample kit? Not any longer. The responsibility of the oil supplier must carry beyond the point of sale—it must be equally concerned with the selection and application of its products. Sample kit and price list selling offers little or no assurance to the bus operator that he is getting the best lubricant for engine, transmissions, rear axles or chassis. Neither will friendship guarantee that the bus operator is receiving those lubricants which will provide the most efficient lubrication. Is it not logical to conclude that successful bus operation depends more upon the buying of lubrication service rather than merely buying oil and grease?

Engine Design

The modern high-speed bus engine is not unlike its forerunner of thirty years ago in basic design. The simple mechanism of the crank and connecting rod has survived the repeated attacks of inventive visionaries and remains today the simplest, most efficient and most reliable mechanism for transmitting reciprocating motion into rotary motion. Broadly speaking, the present state of engine perfection is the direct result of countless refinements in design and materials. Of the latter, we find valve materials with unusual heat-resisting properties, aluminum alloy pistons with greater strength and low expansion coefficients. Cylinder blocks and liners made from alloy cast iron having higher tensile strength, better resistance to corrosion and wear. Crankshafts, connecting rods, and gears made from the newer alloy steels possessing greater tensile strength, unusual hardness and ductility. Bearing metals with tougher properties at the higher operating temperatures.

All of the foregoing developments either directly or indirectly are responsible for producing an engine of greater efficiency, more horse-power per cubic inch of piston displacement and greater reliability. These factors made higher engine speeds practical, thus assuring faster schedules, more reliable transportation, longer periods before overhaul and substantial reductions in operating costs.

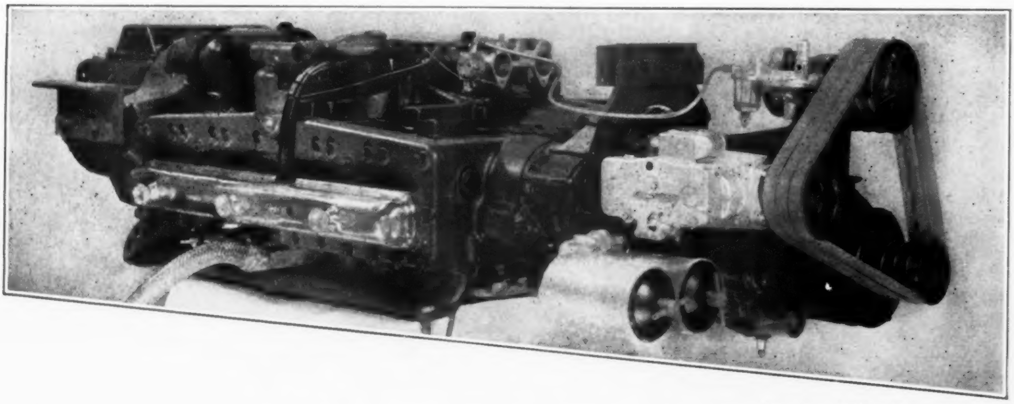
Theory of Lubrication

The commercial success of the modern engine could never have been achieved without first solving the problems of lubrication.

Fundamentally, where two surfaces virtually in contact move relatively one over the other, the phenomenon of lubrication may fall into one of the three following classes:

1. Dry Surfaces.
2. Partial Film or Boundary Lubrication.
3. Full fluid film.

fluid film lubrication. Since an oil of high viscosity develops more friction, a greater quantity of heat will be generated than with a lower viscosity oil. Higher temperature of the oil film will lower its viscosity to the point where equilibrium is reached. The balance between heat developed and heat radiated from the



Courtesy of White Motor Company

Fig. 2—Three quarter front view of 12 cylinder pancake engine. Engine accessories are grouped on the front end for good accessibility. Note the low height of this engine which makes it especially suited for under floor mounting.

In the first case, where two surfaces have no lubricant and operate in the dry condition, the friction is very great and only low loads and slow speeds can exist without seizure. This condition is not found in any normal engine. In fact, it is very difficult to prepare two surfaces which are absolutely dry and clean and free from some substance that may act as a lubricant.

The second condition involving boundary lubrication results in friction being usually quite high and the action of two dissimilar metals may be required to prevent seizure. This condition does not exist in a normal engine for any period of time. It frequently exists within an engine on bearings or cylinders at the time of starting. It is an unstable condition where either an increase in load or a reduction in oil viscosity will increase the friction. The latter increases the temperature which further reduces the oil viscosity and this process may progress rapidly to the point of complete rupture of the film of lubricant and seizure of the moving parts.

The third condition exists where two surfaces are completely separated by a fluid film of lubricant. This is a normal and desirable condition of lubrication. During the last century it was discovered that the coefficient of friction in a journal bearing varies directly with the oil viscosity and speed and indirectly with the load. So that an increase in viscosity will increase the friction or a decrease in viscosity will decrease the friction, just as long as there is

LUBRICANT VISCOSITY NUMBERS

S.A.E. Recommended Practice
CRANKCASE OILS

S.A.E. Viscosity Number	Viscosity Range, Saybolt Univ., Sec.			
	At 130 Degrees Fahr.		At 210 Degrees Fahr.	
	Min.	Max.	Min.	Max.
10	90	119		...
20	120	184		...
30	185	254		...
40	255	...	...	79
50			80	104
60			105	124
70			125	150

OLD CLASSIFICATION FOR TRANSMISSION AND REAR-AXLE LUBRICANTS

S.A.E. Viscosity Number	Viscosity Range, Equivalent of Saybolt Furol Seconds at 100 Degrees Fahr.		Consistency. Must not Channel in service at Degrees Fahr.
	Min.	Max.	
80		79	Minus 10
90	80	149	Zero
110	150	299	Plus 10
160	300	599	Plus 35
250	600		

Saybolt Universal values are approximately ten times Saybolt Furol values for the same oil at the same temperature. (Above as applying to transmission and rear axle lubricants will be discontinued after July 1939).

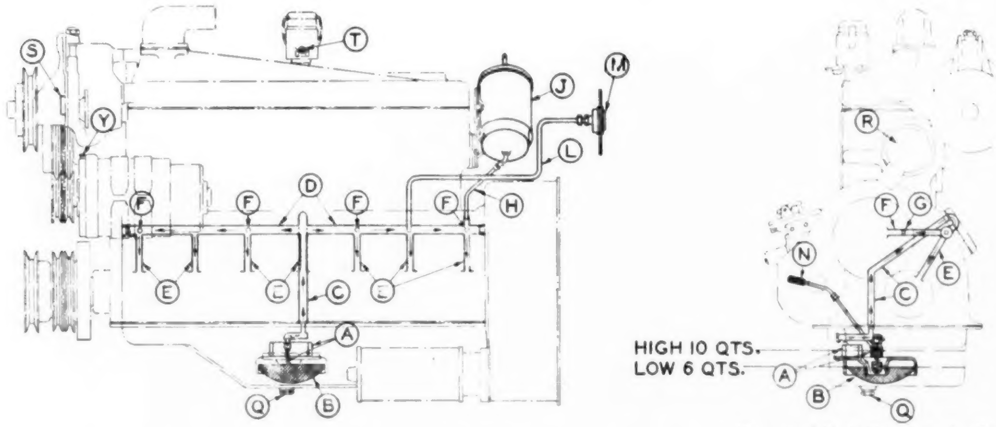
NEW CLASSIFICATION FOR TRANSMISSION AND REAR-AXLE LUBRICANTS

S.A.E. Viscosity Number	Viscosity Range		Consistency. Must not Channel in service at Degrees Fahr.
	Saybolt Universal Seconds	Temperature Degrees Fahr.	
80	100,000 Max.	0	Minus 20
90	800 to 1500	100	Zero
140	120 to 199	210	Plus 35
250	200 Min.	210	

Adopted S.A.E. Lubricants Division, January, 1938.
Reproduced from Society of Automotive Engineers Handbook, Section 2.

bearing will determine the operating temperature of a bearing. The latter will govern the operating viscosity.

For the above set of conditions, viscosity is the only factor which affects friction. The so-called "oilier" oils ironically have no effect upon



Courtesy of Mack Manufacturing Corp.

Fig. 3—Longitudinal and transverse sections of engine oil circulating system. Note how all bearings are supplied oil from the main oil line in the upper half of crankcase.

reducing friction. This point is often misunderstood. The property of oiliness is of importance only when the film of lubricant is broken or where boundary film lubrication exists. "Oilier" oils have the property of reducing metal-to-metal contact for the conditions of broken or boundary film lubrication. For a normal engine operating under the fluid film conditions of lubrication oiliness has no relation to friction.

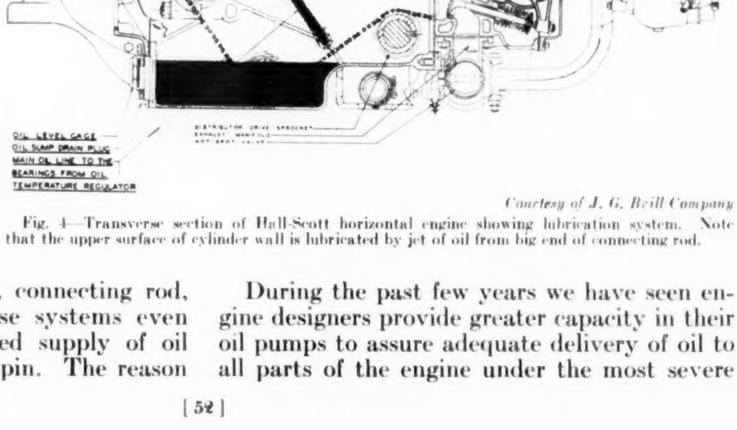
Engine Lubricating Systems

The lubricating systems used by our modern high speed automotive engines may be divided into two classes:

1. Pressure System.
2. Splash System.

Both of the above types of lubricating systems have definite advantages and disadvantages. We find the pressure system almost entirely used today in the heavy duty types of bus engines. In this system, oil is distributed under pressure to all engine bearings, main, connecting rod, camshaft, etc. Some of these systems even make provision for a metered supply of oil under pressure to the piston pin. The reason for favoring the pressure system in the heavy duty bus engine is because it delivers the maximum volume of oil to the bearings. In addition, its greater delivery makes it possible to carry away a larger proportion of heat. In either the pressure or splash systems, the cylinders are lubricated by the amount of oil which escapes from the sides of the connecting rod bearings or from spray holes in the connecting rod. The rate of oil circulation for the pressure system depends primarily upon three factors:

1. Oil Viscosity.
2. Oil Pressure.
3. Bearing Clearances.

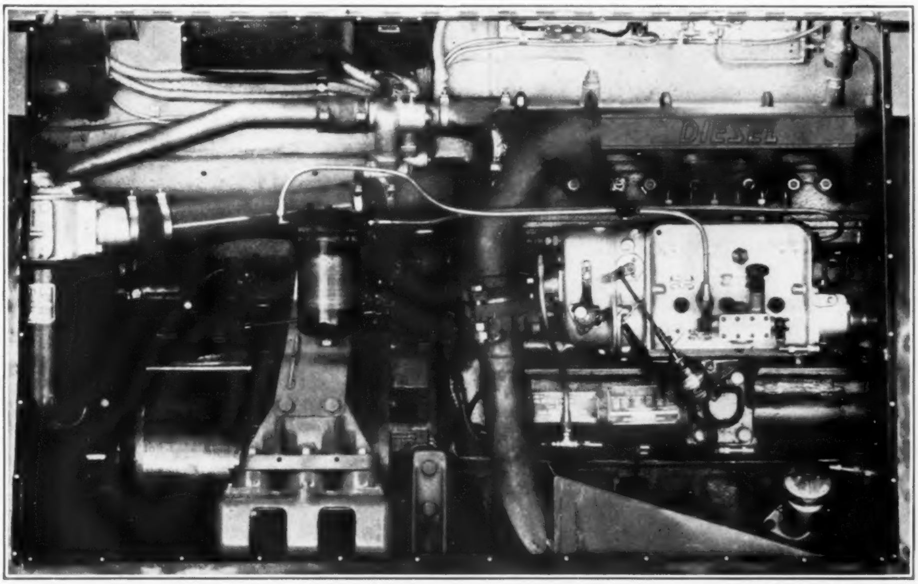


Courtesy of J. G. Brill Company

Fig. 4—Transverse section of Hall-Scott horizontal engine showing lubrication system. Note that the upper surface of cylinder wall is lubricated by jet of oil from big end of connecting rod.

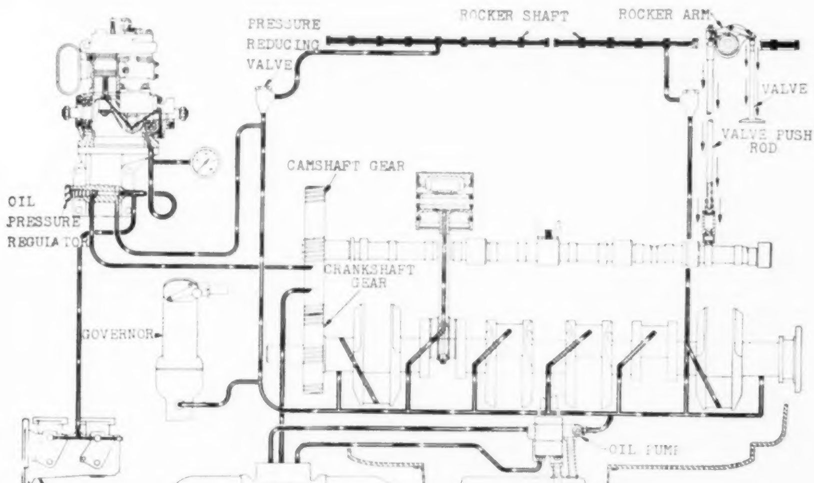
During the past few years we have seen engine designers provide greater capacity in their oil pumps to assure adequate delivery of oil to all parts of the engine under the most severe

conditions of load, high temperatures and low oil viscosities. It was only a few years ago that a badly worn engine required a very high viscosity oil in order to permit the building up of sufficient pressure to assure delivery of oil to all bearings. The bus operator formerly had no choice but to use the very heavy oils in order to maintain a minimum of oil pressure to prevent starvation of any bearings or other parts of the engine. Engine designers have recently made some worthwhile improvements in the oil handling capacity of engine lubricating systems. Improved cooling of cylinder barrels, better bearing design, closer clear-



Courtesy of Twin Coach Company

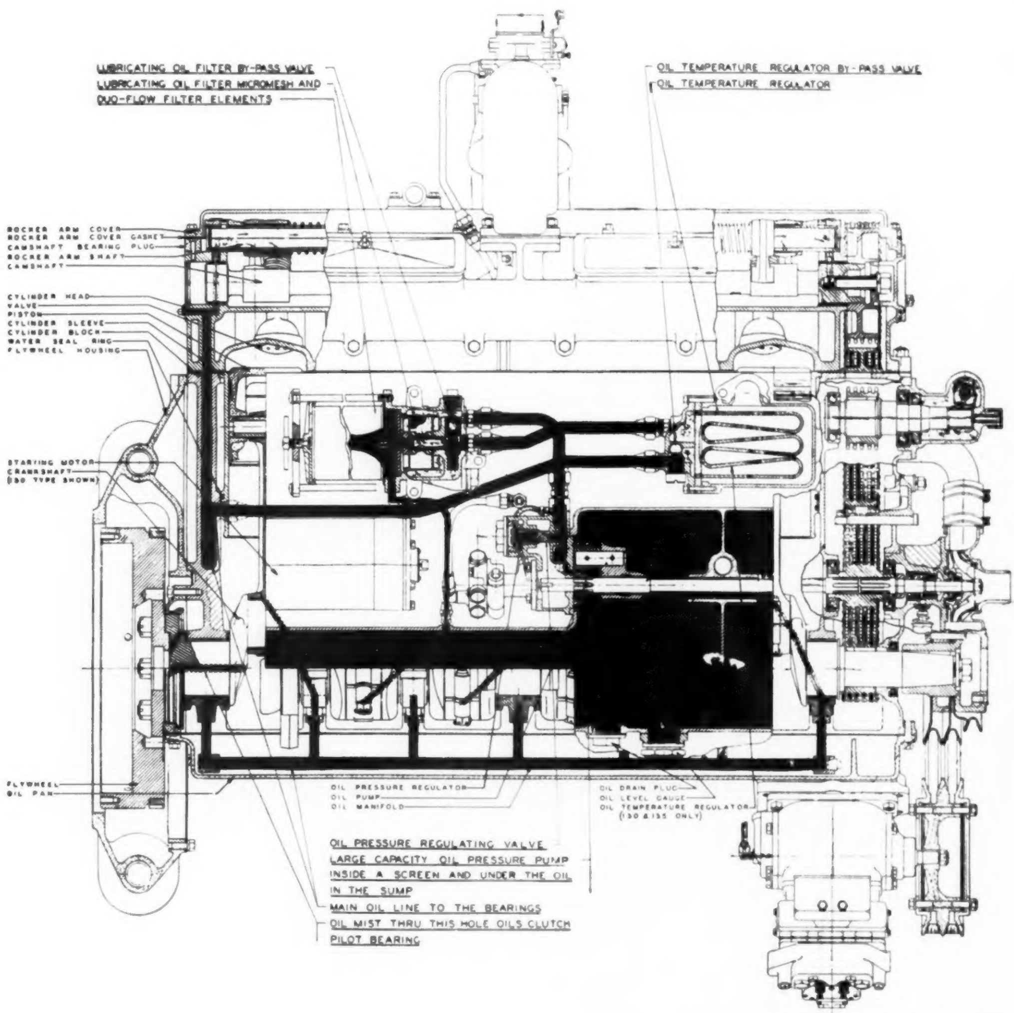
Fig. 5—New Diesel-electric rear end installation. Diesel engine appears at right showing injection pump. Electric generator which appears at left is connected to flywheel housing. The generator absorbs the engine power output and supplies electrical energy for operating the driving motor located ahead of rear axle. The electric drive is becoming very popular with some operators due to their smooth acceleration and great flexibility.



Courtesy of Yellow Truck & Coach Mfg. Co.

Fig. 6—General arrangement of G. M. C. Bus engine lubricating system. Note all bearings, piston pins, air compressor and rocker arms are supplied with oil under pressure.

ances, low expansion aluminum alloy pistons and oil coolers, as well as larger capacity gear type oil pumps, are some of the important improvements made in engine design. The gear type of oil pump is exclusively used on our peratures. Conversely, a high viscosity oil will show a high oil pressure, but actually circulate much more slowly, providing a comparatively smaller supply to bearings and cylinders. With the high viscosity oils we find the engine fric-



Courtesy of J. G. Brill Company

Fig. 7—Sectional plan view of Hall-Scott horizontal engine. Note entire lubrication system including sump, oil pump, filter, cooler and high pressure lines to all bearings.

modern engine. It has some very definite advantages, mainly simplicity, reliability, freedom from clogging and absence of pulsation. Among its limitations we find that it does not have a good suction lift and rapidly loses its volumetric efficiency when worn.

Oil pressure is often mis-construed as a guide to engine lubrication. A low viscosity oil may indicate a low oil pressure but actually will circulate much more rapidly through the bearings, at the same time carrying away a greater amount of heat and lowering the bearing temperatures.

tion increased to such an extent that the greater heat generated reduces the oil viscosity to a point approaching that of the operating viscosity of a lower viscosity oil.

Viscosity

Viscosity determines the amount of bearing friction, heat generation and the rate of circulation through the engine under given conditions of speed, load, design and oil pressure.

The viscosity classification of motor oils is greatly simplified by the S.A.E. viscosity

numbering system shown on page (51). All motor coach manufacturers have carefully worked out S.A.E. viscosity number recommendations to meet all extremes of temperature and operating conditions. These recommendations should be followed to obtain the most satisfactory results.

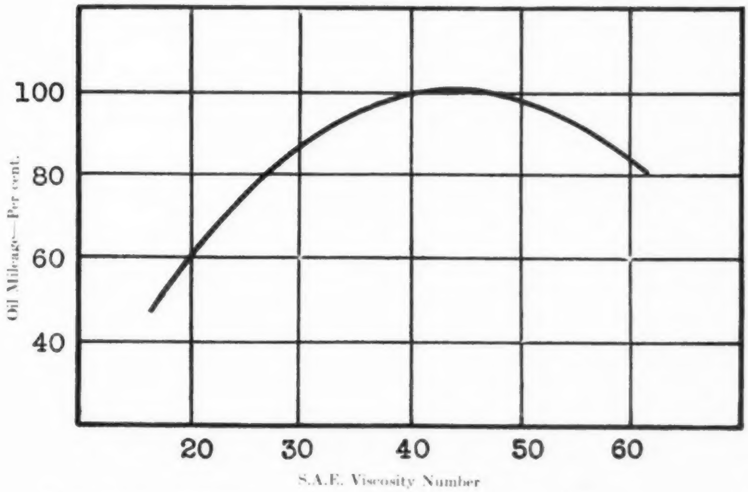


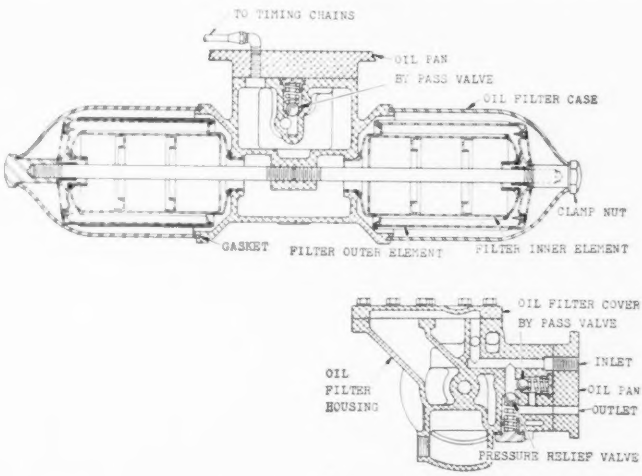
Fig. 8—Relation of Oil Mileage to Viscosity.

A majority of bus fleets are not exposed to starting temperatures much below 40 degrees Fahr. Therefore, hard starting is not usually a problem. However, for those exceptions where buses are exposed to lower atmospheric temperatures the oil viscosity at the starting temperature is very important. To permit the proper cranking speed the oil viscosity should not exceed 40,000 seconds at the lowest expected temperature. For example, an S.A.E. 20 grade has a viscosity under 40,000 seconds (Saybolt Universal) at 0 degrees Fahr., and would be required to permit easy starting at that temperature.

What about the selection of a viscosity grade based upon oil consumption and general lubrication and where low starting temperature is not a factor? Figure 8 shows the relation between oil mileage and viscosity. For average conditions the heaviest grade obviously does not assure the highest oil mileage. This relation, of course, varies somewhat with design, operating and mechanical conditions in each engine.

A very definite trend has taken place within the past two years to break away from the heavy grades of oil, and where the coach manufacturer recommends some of the lighter grades such as S.A.E. 30, the operator should take advantage of this and follow the recommendations instead of continuing with the heaviest grades used in the past. Engine designers recognize that some very definite advantages may be secured by using an S.A.E. 30 instead of an S.A.E. 60 grade. We have already mentioned that there have been numerous improvements in piston ring design, better cylinder cooling to preserve their roundness and straightness, closer bearing clearances, larger capacity oil pumps, and oil temperature regulators, all of which permit the use of an S.A.E. 30 grade without the objection of excessive oil consumption, even during summer weather. Some of the advantages claimed by using an S.A.E. 30 grade against an S.A.E. 60 grade are as follows:

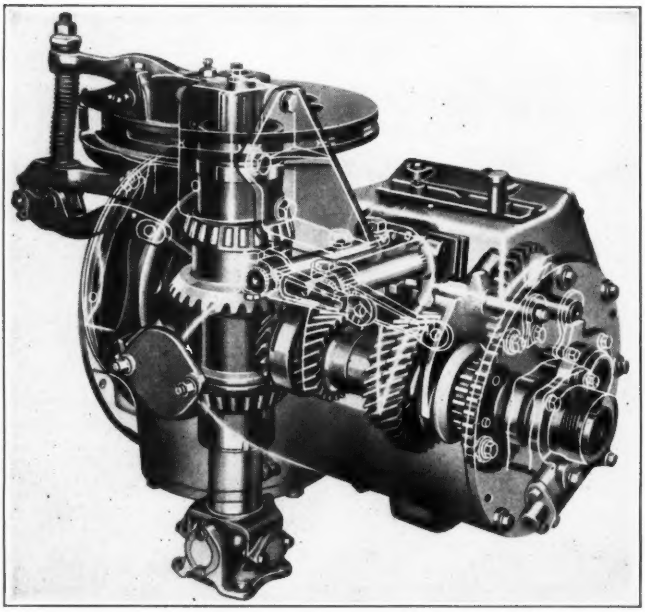
1. Piston scuffing is eliminated.
2. Piston rings remain free and active in their grooves for longer periods.
3. Piston ring wear is reduced.
4. There is a slight improvement in gasoline mileage. (Saving in gasoline often offsets slightly higher cost of oil.)



Courtesy of Yellow Truck & Coach Mfg. Co.
Fig. 9—Sectional view of dual full flow oil filters. Note arrangement of by-pass valve to insure an oil supply to engine in the event of a clogged filter.

5. Bearing temperatures are lower.
6. Starting is easier.

There may be some objection to the trend towards lighter grades where a bus fleet has a majority of "Old Timers" and where the operator prefers to stock only one grade of motor oil. For these cases it is usually necessary to continue using the heavy grades which are required for the older engines.



Courtesy of Twin Coach Company

Fig. 10—Phantom view of transmission used in rear engine installation. Note drive is through bevel gears to vertical shaft which connects to the rear axle.

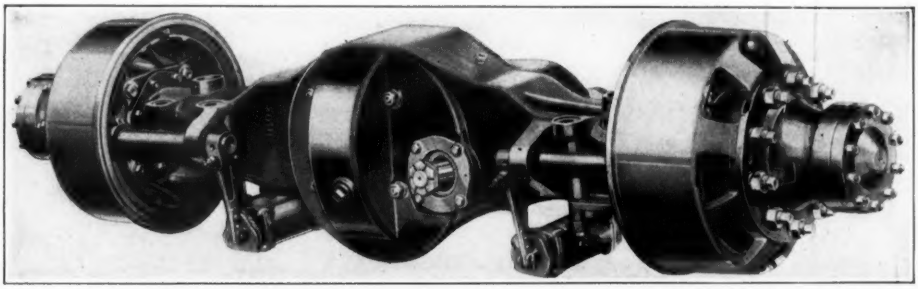
Stability

A good motor oil for bus lubrication must have good resistance to oxidation and good thermal stability. Resistance to oxidation is really the fundamental basis of distinguishing ordinary low cost machine oils from the modern highly refined motor oils. Oxidation stability may be measured by a number of laboratory tests. None, however, have as yet been adopted by the A.S.T.M.* They are quite effective for the purpose of separating the good from the bad but unfortunately a majority of such oxidation tests do not correlate too well with practical operation in view of the variety of operating conditions. Most authorities agree that actual engine operation is probably the best guide yet devised for determining the oxidation resistance of motor oil.

An oil with good stability offers the bus operator the following advantages:

1. Reduction or elimination of sludge within the crankcase.
2. Less danger from clogged suction screens and interrupted oil supply.
3. Freedom from clogged oil lines or passages.
4. Longer life from oil filter cartridges.

All oils in contact with the hot surfaces existing within the engine undergo some chemical change after a period of time. Exposure to either hot blowby gases or the very hot underside of pistons (usually from 300 degrees Fahr., to 650 degrees Fahr.), causes the formation of compounds which, in the initial stage, are soluble in motor oil. These circulate throughout the engine and are not particularly harmful. Their presence is often apparent by the darkened or blackened color of the oil. Further exposure to high temperatures causes these compounds to turn into a black sticky insoluble substance, gummy or tarry in nature, which settles or precipitates from the oil. Such a compound serves as an excellent binder for other foreign materials commonly found in



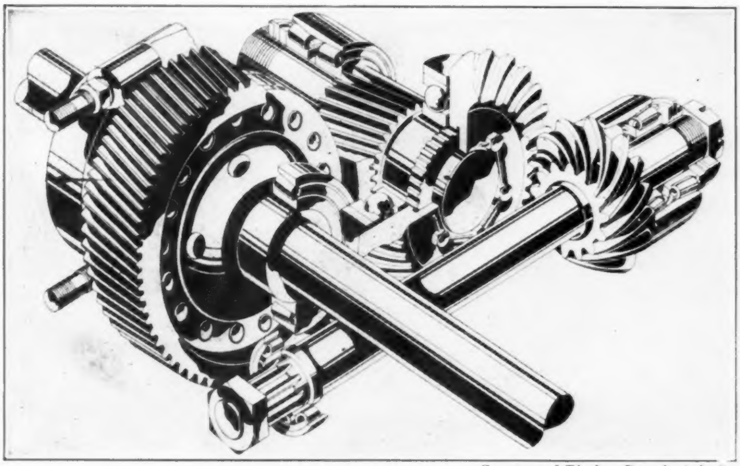
Courtesy of Timken-Detroit Axle Co.

Fig. 11—Exterior view of double reduction hypoid rear axle now fitted to a number of 40 passenger trolley coaches.

*A.S.T.M. American Society for Testing Materials.

used motor oil, such as fuel soot, carbon, metallic oxides, water, dust and etc.

Even though the advantages from the newer refining methods may not be very apparent to the average operator, they indirectly are responsible for the making of some very substantial savings in engine maintenance. The great advantage to the consumer lies in the fact that those hydrocarbons which have poor stability and poor resistance to oxidation can now be easily removed from the motor oil, to save the operator the labor of frequent engine over-hauls and the removal of sludge deposits. Just as the modern heat treated alloy steels tremendously improve the tensile strength, ductility and resistance to fatigue, so does modern refining improve the resistance to breakdown and sludging of lubricants.



Courtesy of Timken-Detroit Axle Co.

Fig. 12—Double reduction hypoid assembly. Note propeller shaft is coupled to pinion shaft extension at lower left and drives through hypoid pinion at upper right.

Carbon Formation

The carbon-forming properties of motor oil are also quite important. Upon these properties depends the amount of carbon which is deposited in the combustion chamber behind piston rings and valves. The established laboratory procedure for measuring carbon residue is made by the Conradson Method. This involves the distillation or evaporation of 10 grams of oil in a crucible from which air is excluded.

Years of operation in numerous bus fleets is the best example of proving the value of a low carbon residue. In bus operation carbon deposits in the combustion chamber from the motor oil are not particularly objectionable except for the fact that they may increase the fuel anti-knock requirements of the engine. Piston ring clogging, on the other hand, is very important. Clogged piston rings or ring grooves hasten the necessity for engine overhaul and prematurely increase oil consumption and loss of power. Obviously, clogging or sticking of piston rings makes it imperative for the engine to be overhauled and new rings installed. Longer periods between engine overhaul offer decided reductions in engine maintenance. Motor oils as refined by modern methods show carbon-forming tendencies from one-quarter to one-half as much as formerly from the same crude.

Pour Point

Where buses are stored in heated garages a low pour point is of secondary importance. On the other hand, if buses are exposed to low atmospheric temperatures, it is important that the pour point be approximately 10 degrees under the lowest anticipated starting temperation in order to insure immediate oil circulation after starting the engine.

The pour point of gear oils should not be overlooked, particularly where buses are exposed to low atmospheric temperatures. This test is some indication of the channeling temperature; the latter is usually about 10 degrees under the pour point. It is quite important that a gear oil be selected having a channeling temperature at least as low as the lowest anticipated starting temperatures.

Flash and Fire

According to the A.S.T.M., flash and fire tests mean nothing in determining the actual usefulness or value of lubricating oils. In general, it may be stated that the use of flash and fire point limits in lubricating oil specifications are often misleading when taken as an indication of the quality of motor oils.

Gravity

The A.S.T.M. also states that the property of gravity is of little significance as an index for the quality or usefulness of a finished lubricating product and its use in specifications is to be avoided.

Oil Filtration

The importance of filtration systems on modern bus engines is apparent since filters

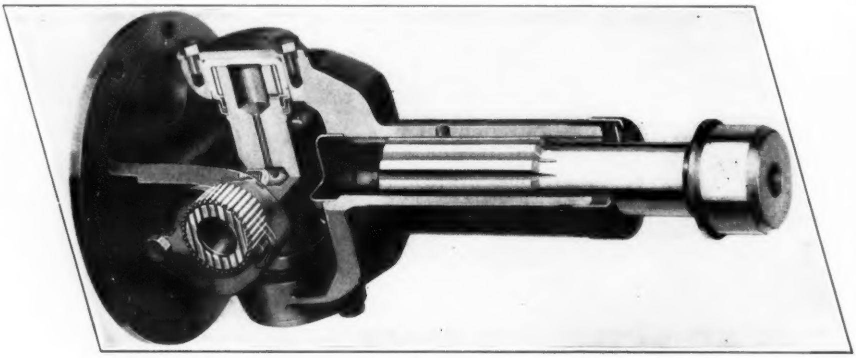
are installed by every manufacturer. There are two distinct types of filtering systems used today:

1. Full Flow.
2. By Pass.

In the first system, all oil must pass through the filter before reaching the engine bearings; this assures the removal of all abrasives when the filter element is cleaned at frequent enough intervals. The second method employs a system whereby a limited quantity of oil passes through the filter from the high pressure lines and then returns directly to the crankcase sump. This method has the disadvantage in that certain solids may circulate through the engine bearings a number of times before reaching the filter. Within the past few years, a number of improvements have been made on oil filters by increasing their size and fineness of filtration. Some oil filters are able to maintain engine oil in a reasonably clean condition, to the end, that a few operators have been tempted to greatly lengthen drain periods or never change at all. Unfortunately, many have found out at the expense of costly engine repairs that the following substances are often deposited, regardless of filter efficiency or type:

1. Water.
2. Carbonaceous Material.
3. Sludge.
4. Oxidized Oil.

The type of oil, operating conditions and engine design control the rate of formation of these materials. Water is probably the most troublesome of the above. Excluding leaks from the cooling system, water collects in the crankcase from condensation of blowby gases. It is well known that about one gallon of water could be condensed from the exhaust gases for each gallon of fuel consumed. At low engine temperatures, found particularly during the winter on local slow speed bus operations, water may condense within the case at an astonishing rate. Normally, new oil and water do not mix, but the reverse holds true when any of the above foreign materials are present.



Courtesy of Spicer Manufacturing Corp.

Fig. 13—Cutaway view of new needle bearing universal joint. An oil type of lubricant is introduced through fitting in center spider.

Carbonaceous deposits within the crankcase are generally formed by the cooking of oil on extremely hot surfaces, such as the underside of pistons. These flakes usually fall into the case and lodge against the pump strainer screen and, therefore, cannot be filtered. A low carbon-forming tendency in the motor oil is desirable to reduce the rate of accumulation. Another equally important source of carbon comes from finely divided fuel soot which has been blown by the pistons and settles into the sump. This material is not especially harmful in itself except that it assists the formation of sludge. It is so finely divided that it can readily pass through the pump suction screen and be circulated with the oil stream up to the oil filter where it may be separated from the oil.

As we have already discussed, all oils react with oxygen if the temperature is high enough, and if the oil is exposed to these conditions for long enough periods. The rate of oil oxidation or oil destruction depends upon the mechanical condition of the engine to a large extent. Excessive blowby is one of the most destructive factors to motor oils. In the case of leaking exhaust valves, the finest valve materials may be quickly damaged by the erosion of gases leaking past the valve and seat which may be as hot as 3,000 degrees Fahr. Similarly, excessive blowby past pistons and rings will burn the film of lubricating oil on the cylinders and pistons. Burned or oxidized oil may be reduced to gummy or tarry deposits which, if present in small quantities in the crankcase will greatly accelerate formation of injurious sludge deposits. These deposits are often found in sufficient quantities on the oil pump suction screen to stop the flow of oil to the engine causing bearing failures. Oil filters frequently do not remove these deposits, and, for this reason, the maintenance personnel of a bus fleet are often given a false sense of security.

Engine maintenance is therefore extremely

important. No oil, no matter how good, has yet been developed that will resist the destructive conditions found in poorly maintained engines. For these reasons, oil suppliers find it quite important to employ highly trained technicians whose function is to assist the bus operator in establishing maintenance and service practices that will reduce the chances of such difficulties taking place. Again, the oil company must be interested in selling lubrication rather than just lubricants.

Transmissions

Five factors are usually considered when selecting a lubricant for transmissions:

1. Viscosity high enough to prevent wear.
2. Resistance to channeling at lowest expected temperature.
3. Stability—must not thicken nor form any solids.
4. Easy gear shifting during cold weather and freedom from gear clashing during warm weather.
5. Leakage—although not related to lubrication, it is often necessary to modify the recommendation to alleviate this condition.

Straight mineral oils are recommended and used almost universally to lubricate motor coach transmissions. They are favored because of their stability and wide source of supply. Manufacturers recommend the following grades, S.A.E. 90, 110, 160 or 250*, depending upon design, temperature and operating conditions. The present designs do not require oils having higher "film strength" or "extreme pressure" qualities. A rather serious disadvantage in using the average type of extreme pressure lubricant in the transmission is based upon their general tendency to attack bronze parts. Some rather enviable performance records have been established with high quality mineral oils. Certain fleets have been able to obtain over 200,000 miles of service from transmissions in heavy duty service before needing repairs.

Universal Joints

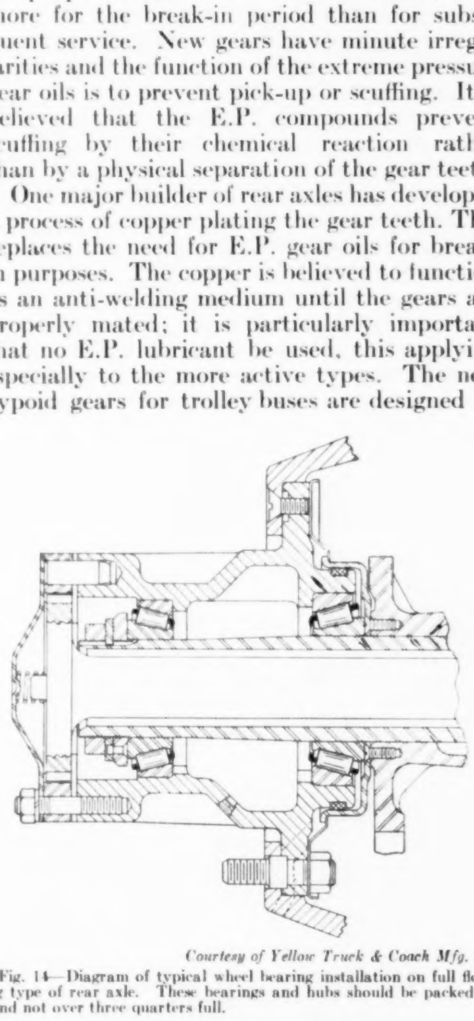
A great achievement has been made by joint builders with the introduction of the needle-bearing type. The problem of lubrication is greatly simplified from the standpoint of both less frequent lubrication required and using the same oil which is used in transmissions or rear axles.

Rear Axle

The worm gear type of rear axle, which was so widely used several years ago, has been wholly replaced by the spiral bevel types. The latter is used with single or double reduction, depending upon the class of service in which the bus is to operate. Hypoid gears have most recently appeared in rear axles of a number of new trolley coaches.

Many years of experience among the bus fleets using worm gears rather definitely established the superiority of straight mineral oils as rear axle lubricants. As for the spiral bevel gears, so widely used at present, it is safe to say that the designers in general are keeping tooth pressures down to moderate values. Although extreme pressure lubricants are recommended by a few bus manufacturers, the purpose of this recommendation is intended more for the break-in period than for subsequent service. New gears have minute irregularities and the function of the extreme pressure gear oils is to prevent pick-up or scuffing. It is believed that the E.P. compounds prevent scuffing by their chemical reaction rather than by a physical separation of the gear teeth.

One major builder of rear axles has developed a process of copper plating the gear teeth. This replaces the need for E.P. gear oils for break-in purposes. The copper is believed to function as an anti-welding medium until the gears are properly mated; it is particularly important that no E.P. lubricant be used, this applying especially to the more active types. The new hypoid gears for trolley buses are designed to



Courtesy of Yellow Truck & Coach Mfg. Co.

Fig. 14—Diagram of typical wheel bearing installation on full floating type of rear axle. These bearings and hubs should be packed by hand not over three quarters full.

operate with much lower tooth pressure than exist in the average passenger cars today. Since the pinion offset is less, the longitudinal sliding motion of gear teeth is also less than in passenger car hypoid rear axles. Hypoid gears of this type, as recently applied to buses, have

*NOTE: A new viscosity number, S.A.E. 140 was adopted January 14, 1938 to replace the present S.A.E. 110 and 160 classification which will disappear in July, 1939. See chart on page (51)

been found to function perfectly with a straight mineral type of gear oil.

Wheel Bearings

Tapered roller bearings are universally used for wheel bearings in motor coaches. These bearings must be lubricated under a wide range of temperatures and operating conditions. In northern climates the atmospheric temperature may drop to -30 degrees Fahr., and under severe operation in southern climate the maximum hub temperature may exceed 250 degrees Fahr. There is a considerable change in consistency of greases with variations in temperature. It has thus far been impractical to produce one grease to meet all conditions. A wheel bearing grease must necessarily be soft enough at the lowest operating temperatures likely to be encountered to furnish good lubrication and yet hard enough to prevent undue leakage. In view of the extremes of operating conditions, refiners find it necessary to produce at least three different grades of wheel bearing lubricant. Soda soap greases are superior for wheel bearing lubrication because they have the highest melting point and will not separate or breakdown when subjected to highest operating temperatures likely to be encountered in the wheel hubs. A wheel bearing grease should have a maximum usable temperature of at least 250 degrees Fahr. For low temperature conditions a soft grease is preferred having an A.S.T.M. unworked penetration of about 300. For a majority of conditions found in the bus fleets, including warm weather operation, a hard grease with an unworked penetration of 210 to 230 is necessary to prevent leakage. In extreme cases where buses operate in heavy duty service in very hot climates, it is sometimes necessary to select a still harder grease with an unworked penetration of 160 to 180 to prevent leakage. The mineral oil viscosity used in wheel bearing greases may vary widely from a minimum of 300 seconds (Saybolt Universal) at 100 degrees Fahr., to a maximum of 175 seconds (Saybolt Universal) at 210 degrees Fahr. The percentage of soda soap may vary from 7 per cent. to 30 per cent. depending upon the oil viscosity and the desired consistency. A majority of bus operators prefer a wheel bearing grease having a high mineral oil viscosity.

In lubricating wheel bearings the leading operators find it quite important to thoroughly apply the grease inside of the cage, after washing, cleaning and drying the bearing.

Chassis Lubrication

There are four important requirements of a good chassis lubricant:

1. Last for long periods
2. Adhesive quality.
3. Form protective seal against water, sand, road dust, etc.
4. Water resisting.

Three basic types of greases are commercially available for chassis lubrication, namely, calcium, aluminum, or soda soap base. All of these types generally range in consistency from semi-fluid to an unworked penetration of 300. The calcium soap greases have been in use for the longest period. They are yellow in color, smooth in texture, and contain a low viscosity mineral oil of about 300 seconds Saybolt Universal, at 100 degrees Fahr. These greases are insoluble in water, have a very low melting point and will readily leak out at even moderate temperatures. For chassis lubrication in bus service this type has given way almost entirely to soda soap greases.

Greases made from aluminum soap are light amber in color and are quite adhesive. They are not soluble in water, however, water has the effect of destroying the adhesive properties.

Soda soap greases have the highest melting point of the three types mentioned. These greases have the advantage of good stability and will not separate at temperatures in excess of 250 degrees Fahr. For this reason they are preferred for ball and roller bearing lubrication. While these greases are usually considered soluble in water the exact opposite has been found to exist where such a grease contains a low soda soap content under 8 per cent. in combination with a very high viscosity cylinder stock of 4000 seconds Saybolt Universal at 100 degrees Fahr., (175 sec. S.U. at 210 degrees F.) A soda soap grease having these properties is unusually water resisting to road wash. An adhesive texture is very essential for two reasons. First to form a seal or dam around the chassis parts, to exclude water, dust or sand. Second, to resist the squeezing out and dropping off under road shocks and loads.

Summary

Although our discussion has been largely confined to the lubrication of motor coaches, the same principles nevertheless apply to trolley coaches with the exception of the power plant. This discussion has been of a general nature in view of the wide variations in engine and coach design, as well as variations found in operating and maintenance conditions. It is our hope that these few points may assist the operator in the selection of lubricants and enable him to reduce maintenance costs. It is generally recognized that carefully selected lubricants applied at regular intervals is the most effective preventative maintenance yet devised for motor coaches.

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